

## INTRODUCTION TO THE JAWS PROGRAM

John McCarthy  
Director, JAWS Project  
National Center for Atmospheric Research

The JAWS Project is the Joint Airport Weather Studies Project conceived in 1980 jointly between the National Center for Atmospheric Research and The University of Chicago. Funding has come primarily from NSF, FAA, NASA, and NOAA. The JAWS Project is a multi-agency program that, in a sense, is only loosely coordinated. The aspect of the simulation work has been coordinated through the ad hoc committee. Some of the members are listed in Figure 1: McCarthy and Wilson at NCAR; Fujita at The University of Chicago; Walt Frost, who has been heavily involved in the program since the early days through The University of Tennessee Space Institute and FWG Associates, Inc.; Dennis Camp with NASA Marshall Space Flight Center; a number of members at NOAA are directly involved in the program; The University of Wyoming; Alan Woodfield from the United Kingdom; and Lloyd Stevenson from DOT's Transportation Systems Center. Industry has also been involved. For example, United Airlines, through their Flight Training Academy at Denver, has been involved in simulation work. Boeing and Douglas have been involved. It is a rather loosely knit group of people trying to get the job done. We are well coordinated in some ways and in some ways, not so well coordinated.

The objectives of the program have been threefold: 1) Basic scientific characterization, primarily of the microbursts and the statistics of microburst occurrence: we are putting a great deal of effort into understanding the mechanisms which cause microbursts; 2) Detection and warning: we have looked hard at the Low-Level Wind Shear Alert System (LLWSAS) in terms of how well it operated in our program and how it needs to be improved; 3) Doppler radar and airborne systems: we are not directly involved in airborne systems at NCAR, so we are looking at that less hard than at the ground-based Doppler. In aircraft performance, we are concentrating a lot of effort on the very serious issue of pilot awareness. Pilots, unfortunately, are just not terribly aware. We are disseminating information on the program in terms of awareness and certain aspects of training issues, as well as the issue of simulation which is just a piece of the puzzle. Our primary goal is to provide the most realistic three- and four-dimensional microburst data suitable for simulation for government and industry. What government and industry choose to do with these data sets is undetermined. There are probably as many interests in doing something with these data sets as there are people. There are many directions in which you can go. Our objective has been this: given that the SRI profiles are limited, as Herb Schlickermaier has described (ref. 1), can we do better? The answer is absolutely yes. It is also our objective, along with that of the ad hoc committee, to disseminate the best data sets that we can.

The impetus for the program was Fujita's analysis of Eastern 66 and Continental's analysis of Continental 426. In putting the JAWS Project together, we felt that we did not properly understand the convective microburst. I think everybody here knows the implication of a microburst, that it is not good on approach or takeoff if you encounter one. We chose Stapleton because Continental 426 crashed there on takeoff. We had reason to believe there were lots of microbursts there. During JAWS, we had

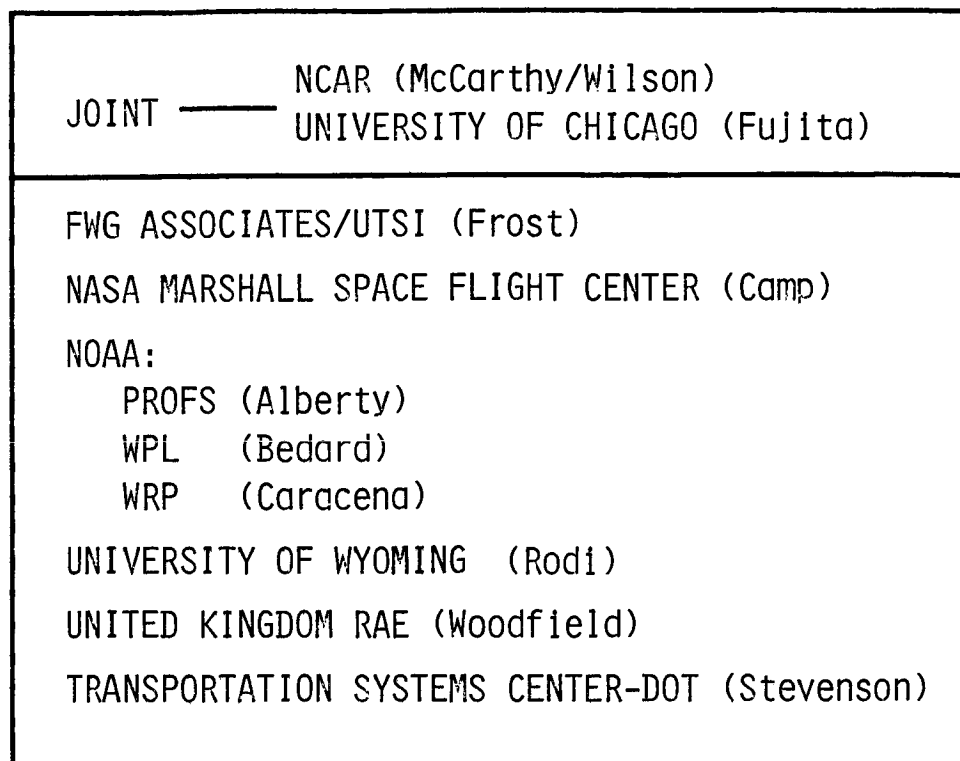


Figure 1. Key members in JAWS Project.

far more microbursts there than we had ever dreamed could possibly occur over an airport, thus justifying our hopes.

The focus of the program was multiple Doppler radar, as reflected in Kim Elmore's report (ref. 2). We had three Doppler radars located in and around Stapleton. We had 27 surface wind measurement systems to try to get as much high-resolution information as we could. We used aircraft and we had our own wind-measuring systems distributed around the airport in addition to the LLWSAS, which was recorded for the JAWS Project. One of the three Doppler radars used was located across from the terminal building. Figure 2 shows a hook echo from an Oklahoma severe thunderstorm for a radar located nearby. We are looking at conventional intensity for a Doppler radar. If we look at it on the Doppler channel, it shows the location of a mesocyclone with winds moving toward and away from the radar; and the Doppler very nicely shows the location of a circulation which is about 15 or 20 km across. Near the center of the circulation is an actual tornado. Doppler is primarily a wind-detecting system and is the basis for developing the NEXRAD program which is the new development of Doppler throughout the United States. Figure 3 shows another sequence to give you another notion of the use of Doppler radar. The figure shows a line of heavy thunderstorms near Sacramento, California, which have two thin spots, however. PSA chose to go through the thin spot which, in fact, appeared as a hole on his X-band radar. The Doppler channel, on the other hand, shows an intense shear southeast in the other. A shear detector on the radar, where the maximum color change shows the maximum shear, indicates the spot he chose to go through was a maximum. So, what appeared to be an actual hole on his airborne radar was the location of a tornado cyclone. The tornado hit the ground ten minutes after he went through. He did get through, by the way, but just barely. At the same time he went through, there was a tornado on the ground just outside Sacramento. So, those are the kinds of things that Doppler can do.

Figure 4 is a Doppler of a microburst, taken from reference 3. The microburst has hit the ground, and spread out in all directions; but we see only the flow toward the radar or away from the radar. The distance between is about 2-1/2 km and the velocity difference shown is about 70 kt across about 8,000 ft. That is at the ground or close to the ground.

Figure 5 shows a direct hit of a microburst on the NOAA P-3 airborne Doppler system, which flew right through the middle of the generation region at 20,000 ft. The system looked straight down, and captured the downdraft of a microburst right in the center.

I have been using the next two figures in pilot-awareness talks. Pilots know not to go down the road, but to go either right or left in the kind of situation shown in Figure 6. This is nothing new; and everybody knows to dig a hole with your bare hands when you see something like this coming. Figure 7 is Fujita's famous picture at Stapleton, with high-based virga, no thunderstorm, and wind shear at the surface in a microburst...a very benign appearing situation which is quite severe and very similar to the appearance during the Continental 426 accident at Denver. Figure 8 is a picture of a high-based virga coming down and a dust cloud on the ground. It is a very benign appearing picture, but probably conceals very dangerous wind shear.

ORIGINAL PAGE IS  
OF POOR QUALITY

16:30:30 2 May 1979

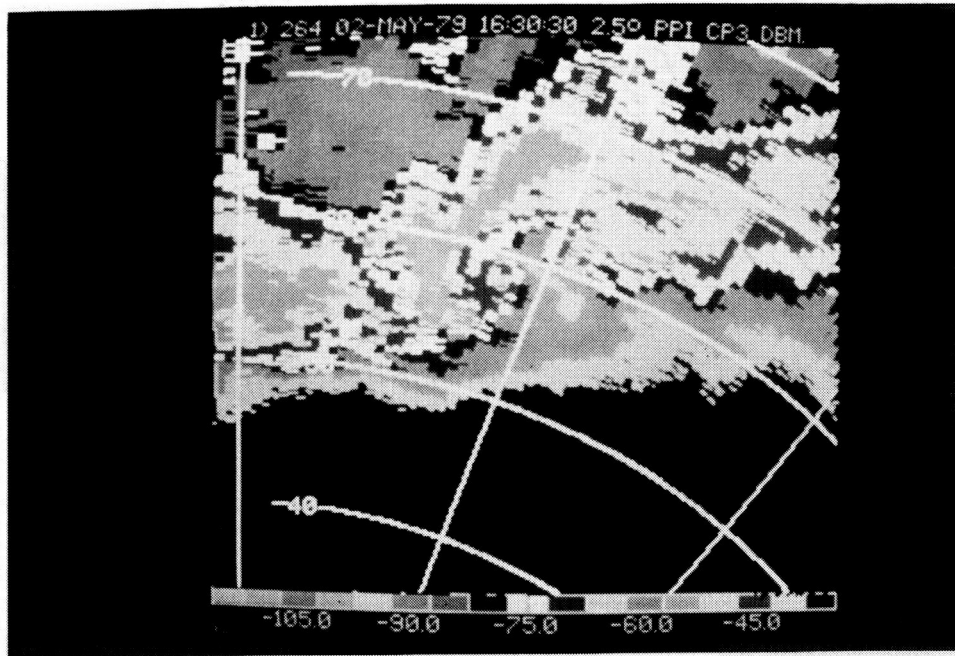


Figure 2a. Hook echo seen in radar reflectivity for an Oklahoma tornado storm.

16:30:52 2 May 1979

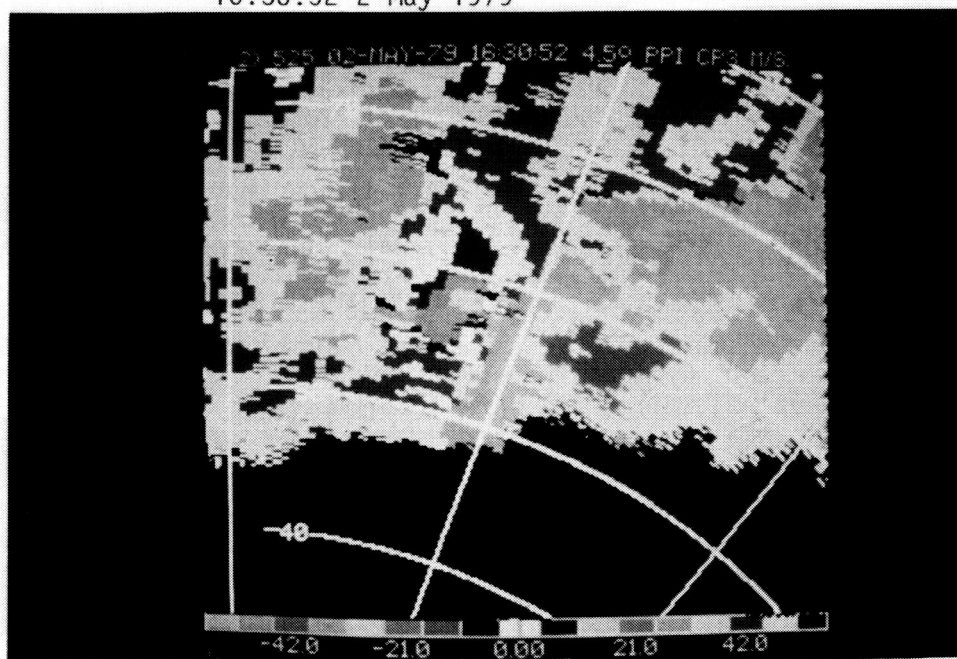
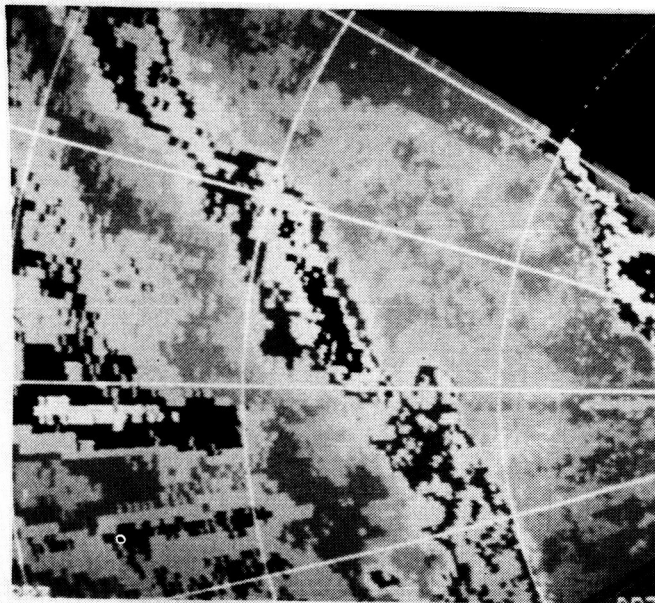
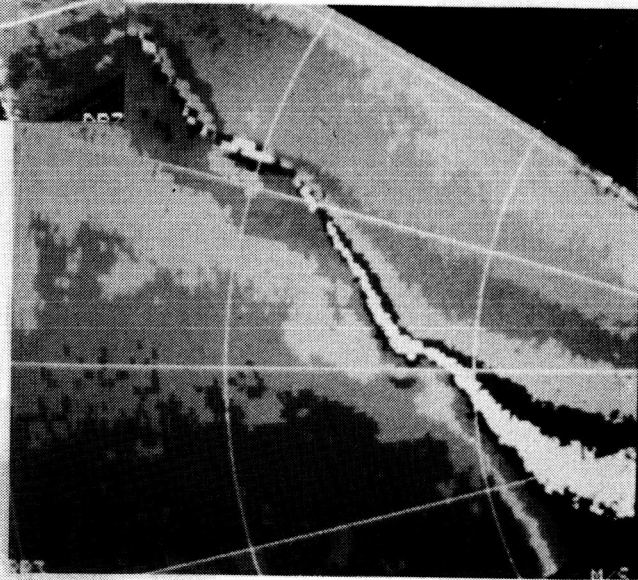


Figure 2b. Associated Doppler velocity picture of same, showing meso- and tornado-cyclone.

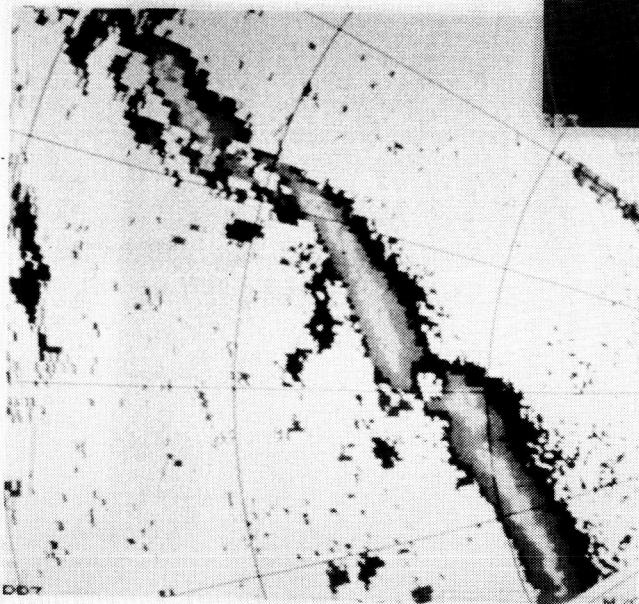




(a) Reflectivity



(b) Doppler radial velocity



(c) Radial Shear

Figure 3. Series of three data slides showing a line of heavy thunderstorms near Sacramento, California, which contains severe shear.

ORIGINAL PAGE IS  
OF POOR QUALITY

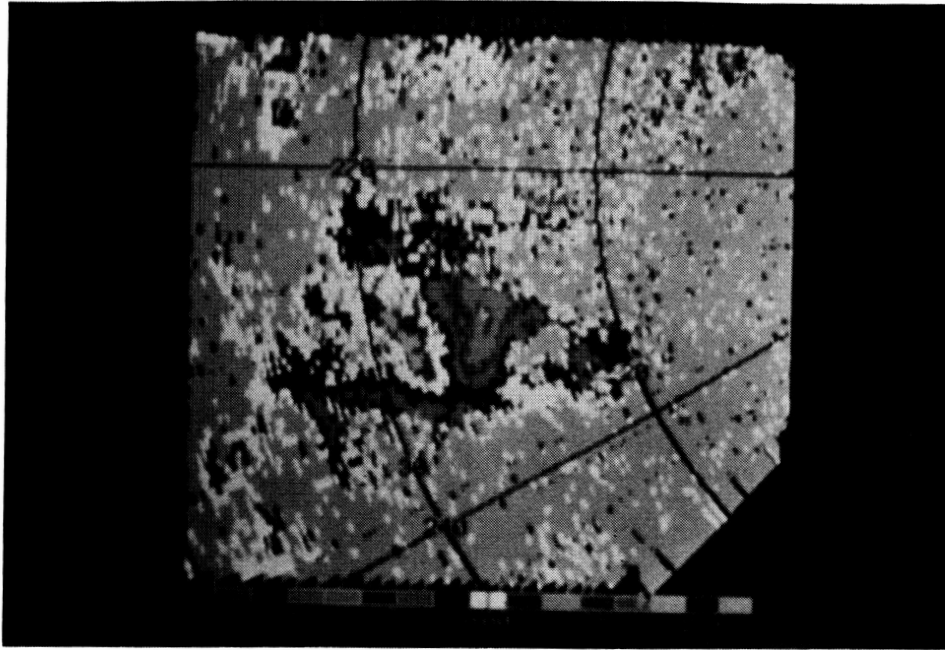


Figure 4. Doppler display shows a wind direction change within a distance of two miles. The bottom scale indicates radial winds in m/s (multiply by approximately 2 to obtain knots). (From ref. 3.)

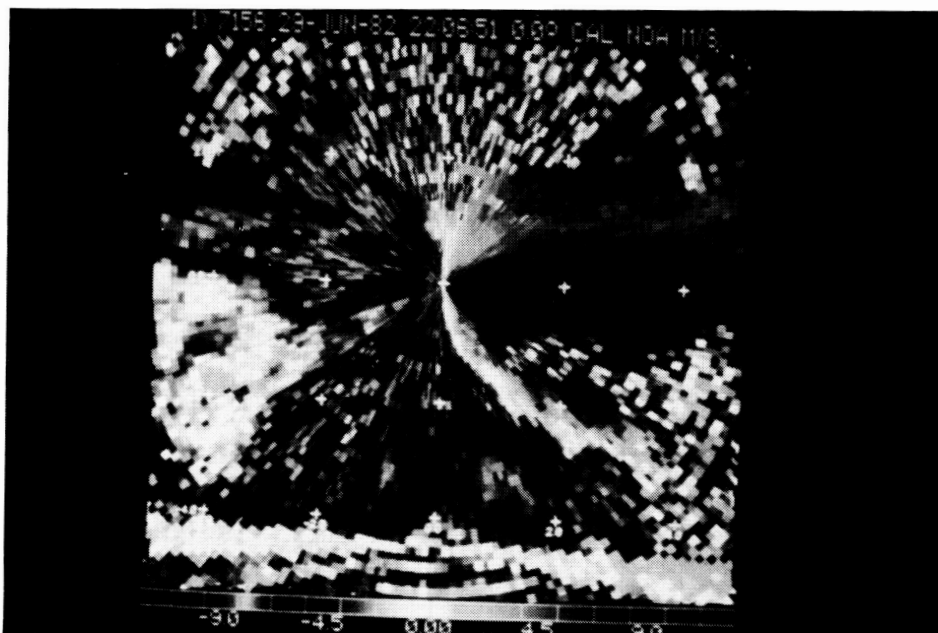


Figure 5. A direct hit of a microburst is shown as seen by the airborne Doppler radar aboard the NOAA P-3 aircraft, looking straight down from 20,000 ft.



Figure 6. Example of traditionally avoided weather hazard.



Figure 7. Picture by T. T. Fujita, University of Chicago, showing benign-looking high-based virga over Stapleton with no thunderstorm.

ORIGINAL PAGE IS  
OF POOR QUALITY



Figure 8. Picture of high-based virga and a dust cloud on the ground; while benign appearing, probably conceals dangerous wind shear.



Figure 9. Microburst embedded in heavy rain, similar to the Pan Am 759 or Eastern 66 situation.

Figure 9 is much more like Pan Am 759 or Eastern 66 with heavy rain. There happens to be a microburst in there, but all you see is the heavy rain. You have to be aware of both situations. Figure 10 shows a ring of dust, a picture taken during JAWS in a microburst. Another picture, Figure 11, shows the incredible vortex circulation associated with the leading edge of a microburst.

Finally, Figure 12 shows a downdraft, an outflow, which is described by the author of this print, published in England in 1671 (ref. 4). We think we are pretty smart, but the downdraft is not new!

Figure 13 shows the biggest microburst hit of the summer which occurred directly over Stapleton. An 85 kt differential along the runway axis was measured between two stations approximately one runway length apart. This means that there is an 85 kt loss in head wind component if you choose to go in either direction down runway 35 or 17.

One of the things that I have recently tried to do is document microburst events (ref. 5). Many of these are out of the National Academy report (ref. 6). Our reporting base is the United States to a large degree. Documented are: A) the confirmed microburst events; B) what we think were microburst events; and C) what might have been a microburst event. The worldwide distribution is significantly less. We don't think our document is complete by any means, but the view is that microbursts are occurring anywhere where convection can occur. We feel pretty certain about that. Time of day at Denver--clearly afternoon convection. No big surprise. Our thunderstorms occur in the afternoon at Denver. At Chicago, they are more likely to occur at night. That's when the maximum number of thunderstorms occur at Chicago. Those are the only two locations where any kind of high-resolution system has been set up to look at microbursts. Beyond Chicago and Denver, we don't know the frequency of microbursts, although we think it's a lot higher than we ever imagined.

Some basic statistics from JAWS: the maximum observed by Doppler radar average is 24 m/s, or approximately a 50 kt differential between the two outflows from the microburst. That is, the velocity change from peak positive to peak negative averages about 24 m/s. When they are first detected by Doppler, they are a little less than 2 km across, and at their maximum intensity, they appear to be about 3 km or nearly 10,000 ft. across. They are small. They last somewhere between five and 10 minutes before they become large-scale flows or before they dissipate. If you look at all the velocity differentials for all of the cases that we saw on Doppler radar, you end up with an average of again about 25 m/s, and the maximum that we have clearly been able to measure was about 48 m/s differential, which is 107 mph. The Pan Am 759 microburst as documented by three different sources is 24.5 m/s. So, it was an average value for a JAWS microburst at Denver that brought down Pan Am 759.

If you look at radar reflectivity or classical intensity as a function of wind speed difference, over half of our microbursts occurred in nonthunderstorm situations. All of them occurred with rainfall or virga, but our strongest microburst occurred in a nonthunderstorm situation. So, classical thunderstorm wisdom does not necessarily buy you a thing in terms of avoiding microbursts.

Of 97 microbursts in this particular statistic, a new and very full-circle kind of finding is that 60% occurred in the vicinity of gust fronts. About 25% of them occurred in families, i.e., where one occurred, many more were going to occur. Some of them were associated with gravity waves.



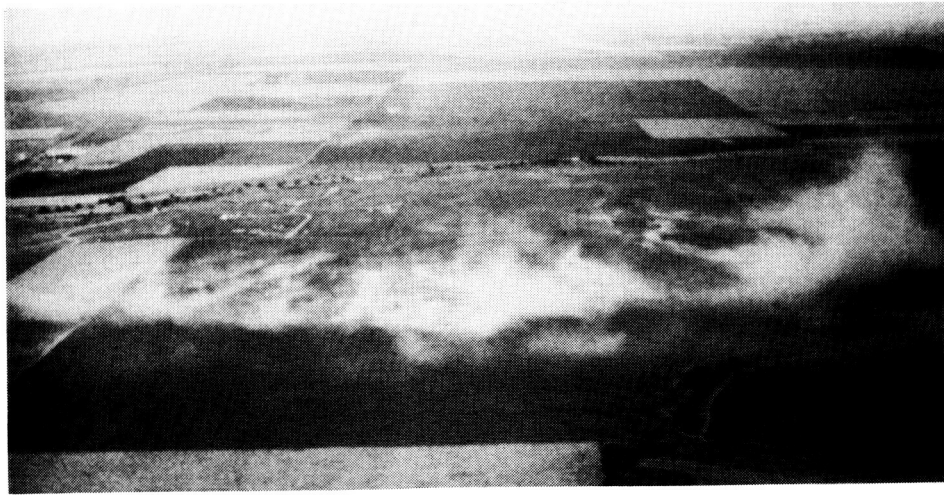


Figure 10. Ring of dust from outflow of a microburst .

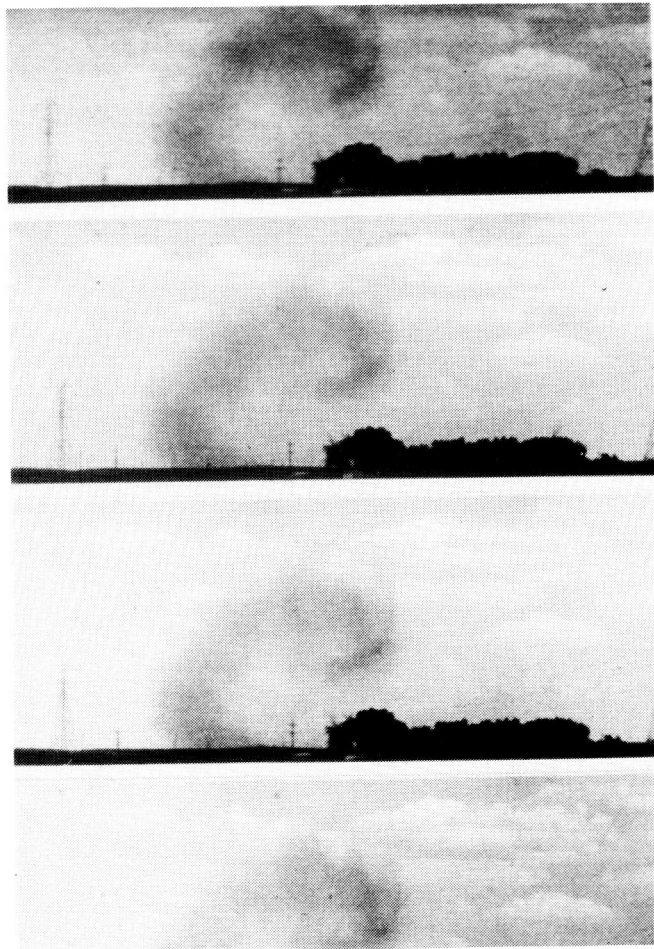


Figure 11. Picture depicts the incredible vortex circulation associated with the leading edge of a microburst.

ORIGINAL PAGE IS  
OF POOR QUALITY

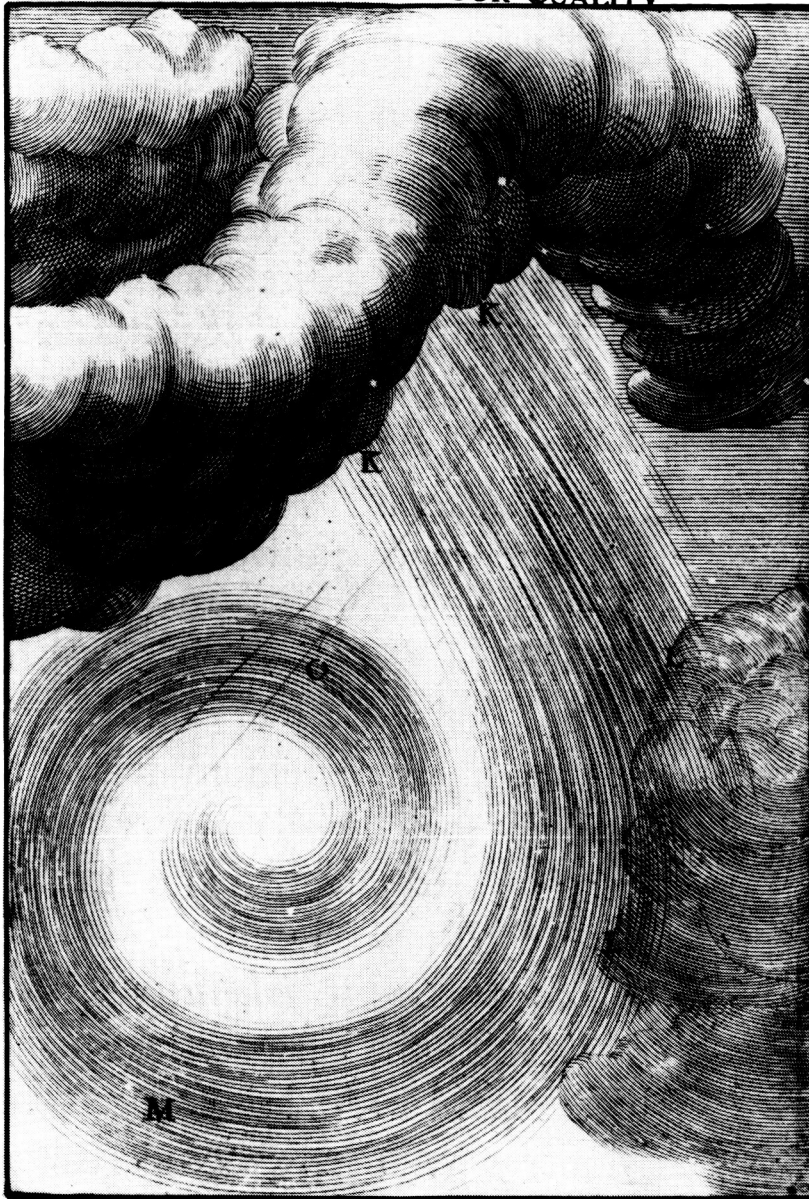


Figure 12. Oxford fellow R. Bohun wrote A Discourse Concerning Origine and Properties of Wind in 1671 (ref. 4). He describes a sudden puff of wind that descends violently down perpendicularly toward the earth. While we take liberties with his description, his drawing is certainly suggestive of microburst features.

The beginning of what multiple Doppler radar will tell you is that on a very high resolution, we can give you what a microburst wind field looks like. There is horizontal flow near the ground with outflow in all directions. The outflow is not uniform and it is not symmetric.

The LLWSAS was looked at very heavily and the results are reported in reference 7. Figure 14 is the distribution of LLWSAS alarms by time of day for the summer of 1982; this is not the distribution of microbursts by day over the airport. The two distributions are different. The resolution of the LLWSAS is 3 km - 6 km, microburst resolution is 1 km - 3 km. So, there are some problems in the algorithms and in the network geometry. We are trying to help in that situation.

NCAR is also peripherally involved in trying to deal with where to put a Doppler radar near an airport, if FAA continues to develop a terminal Doppler radar. I thought I would show you the scenario in Figure 15, which is kind of exciting. The microburst on 14 July occurred off the east end of the runway. The Transportation Systems Center at DOT, Boston, has put together an hour's worth of air traffic movements at Stapleton during this microburst encounter. A Frontier aircraft on approach drops from 700 ft. to 300 ft. in seven (7) seconds, executes a missed approach, and reports the incident on the radio at the same instant the LLWSAS went off. So, they both saw it together. We would like to see it somehow different from that. American 17 right behind Frontier encountered the same thing with a missed approach. Frontier 244, however, didn't believe it yet, so he came back and got back in line and made another missed approach at 2:13 p.m. American 17 didn't believe it either and got back into line for another missed approach, along with a third aircraft. They decided at that point they didn't like runway 26 left, so they decided to come around to 08. The first aircraft through is American 17, who encountered a wind shear at 50 ft., decided he didn't like 08. Of course, they then tried runway 35. At the time they just opened 35 approach, a microburst occurred on the north but now there was nothing on the south end. Continental 414 then approached and got a "sinker" followed by Western 364 who verified a "sinker." After that, operations at Stapleton Airport were closed for about 30 minutes.

Currently, we have analyzed in detail an August 5 microburst case. Data is resolved to a 150 m x 250 m grid. We are currently developing wind profiles from these data and flying aircraft through them with head wind, downdraft, and tail wind. These are the basic wind shear models that we are talking about at this workshop. We have wind fields that are derived from multiple Doppler radar to give you this kind of resolution for three-dimensional and four-dimensional winds. We have a case coming off the press now which gives you a snapshot of the microburst every two minutes for eight or nine minutes total time. You can see the microburst forming and descending, and nobody has really looked at it yet except for us. There have been simulations with a computer model (ref. 8) as to what happens to an airplane when penetrating these winds. These are the data sets that we are preparing for the simulation community.

We have developed a training slide which says that we are convinced that some microbursts can only be flown if some sort of energy trade procedure is flown; and some microbursts, we believe, cannot be flown at all--although we have not proven that yet. Dave Simmon from United presents information to suggest that there are certain procedures that will at least get you through quite a few microbursts (ref. 9).



ORIGINAL PAGE IS  
OF POOR QUALITY

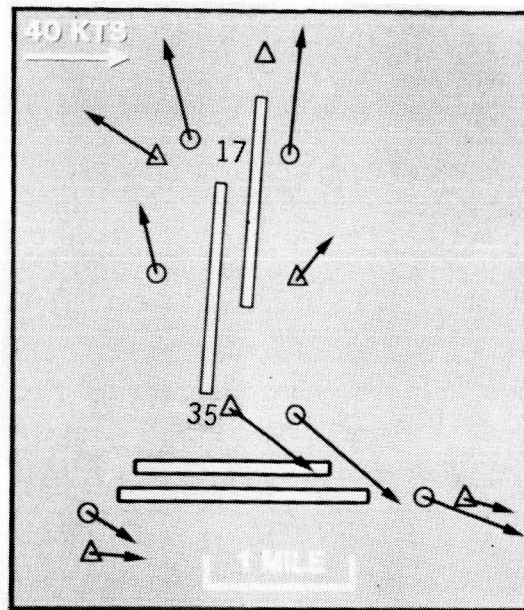


Figure 13. This was the biggest microburst during the summer of 1982 which occurred directly over Stapleton. An 85 kt differential along the runway axis was measured between the two stations, approximately one runway length apart. An aircraft would experience an 85 kt loss in head wind component along runway 35 or 17.

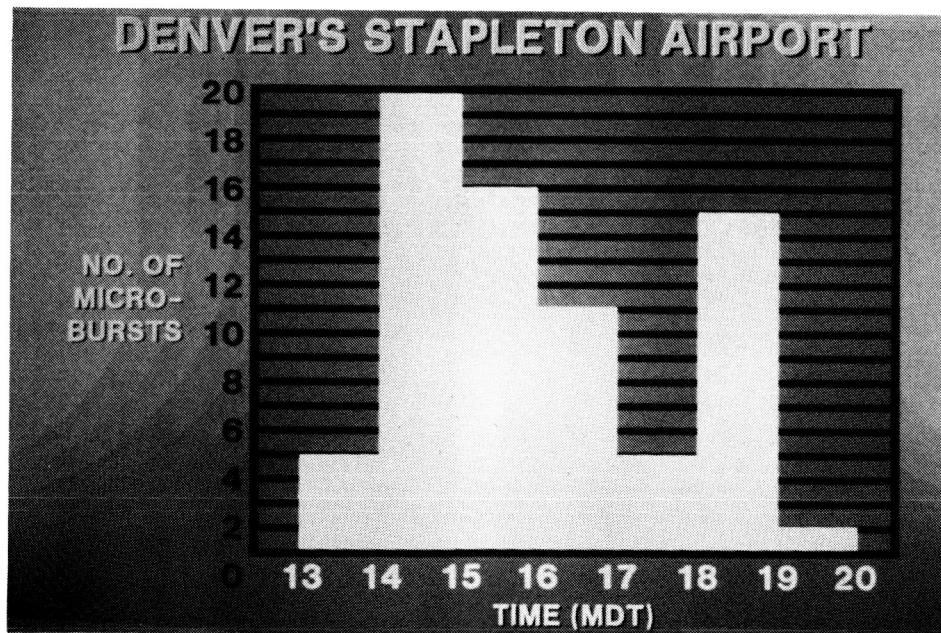


Figure 14. Distribution of LLWSAS alarms by time of day for JAWS during the summer of 1982.

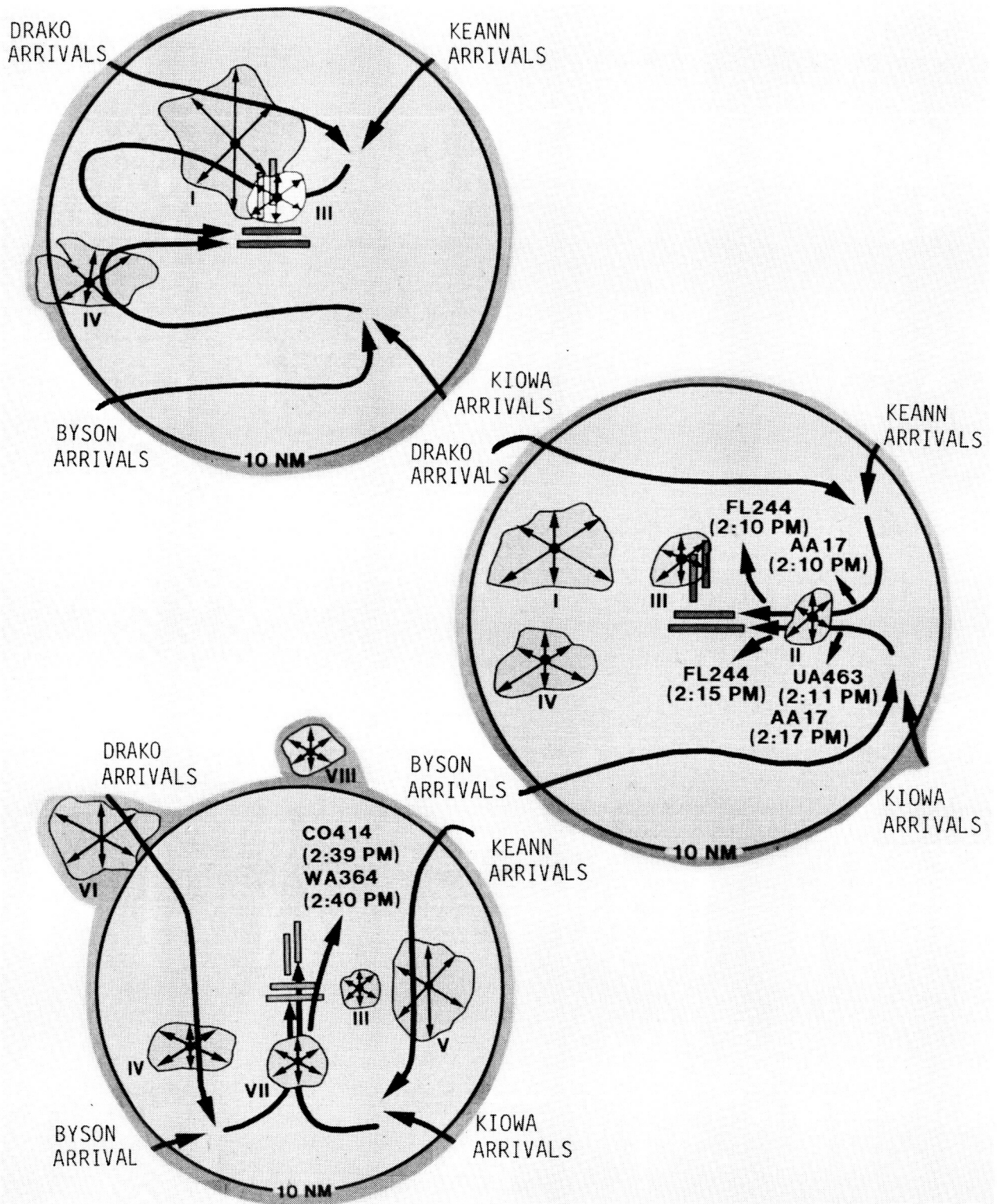


Figure 15. July 14 microburst events over and near Stapleton Airport, showing an hour's worth of air traffic movements at Stapleton during the encounter as described by the DOT Transportation Systems Center. There were several close calls, and numerous missed approaches (sequence of three pictures).

## REFERENCES

1. Schlickemaier, Herbert: Case history of FAA/SRI wind shear models. Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification, NASA CP-2474, 1987, pp. 3-10.
2. Elmore, Kim: JAWS multiple Doppler derived winds. Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification, NASA CP-2474, 1987, pp. 29-42.
3. Microburst phenomenon. MD Flight Approach, no. 42, Apr. 1984, pp. 1-24.
4. Bohun, R.: A Discourse Concerning Origine and Properties of Wind. Oxford Univ., by W. Hall for Thomas Bowman.
5. McCarthy, John, and James W. Wilson: The microburst as a hazard to aviation: structure, mechanisms, climatology, and nowcasting. Proceedings Nowcasting II Symposium, Norrköping, Sweden, 3-7 Sept. 1984, pp. 21-30.
6. Low-Altitude Wind Shear and Its Hazard to Aviation. Report of the National Research Council Committee on Low-Altitude Wind Shear and Its Hazard to Aviation, National Academy Press, Washington, D.C., 1983.
7. Bedard, A. J., Jr., J. McCarthy, and T. Lefebvre: Statistics on operation of the low-level wind shear alert system (LLWSAS) during the JAWS project. DOT/FAA/PM-84/32, Dec. 1984.
8. Frost, Walter: Modeling and implementation of wind shear data. Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification, NASA CP-2474, 1987, 49-66.
9. Simmon, Dave: United Airlines wind shear incident of May 31, 1984. Wind Shear/Turbulence Inputs to Flight Simulation and Systems Certification, NASA CP-2474, 1987, pp. 233-234.